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(54) **Common rail fuel system**

(57) A common rail fuel system for an internal combustion engine includes a common rail fuel volume for supplying pressurised fuel to a plurality of fuel injectors of an engine and a unit pump assembly (8) for supplying pressurised fuel directly to the rail volume. The pump assembly has a pumping plunger (10) that is reciprocable within a plunger bore (14) provided in a unit pump housing (16) under the influence of a drive arrangement (18, 20) to cause fuel pressurisation within a pump chamber (12). The drive arrangement includes a drive member (20) coupled to the plunger (10) to impart drive thereto, in use, so that the plunger (10) performs a pumping cycle including a pumping stroke and a return stroke, and a spill valve (46) which is operable to control whether fuel is pressurised within the pump chamber (12) during the pumping stroke of the plunger (10). An outlet valve (58) controls the supply of pressurised fuel from the pumping chamber (12) to the common rail fuel volume in circumstances in which the spill valve is closed.

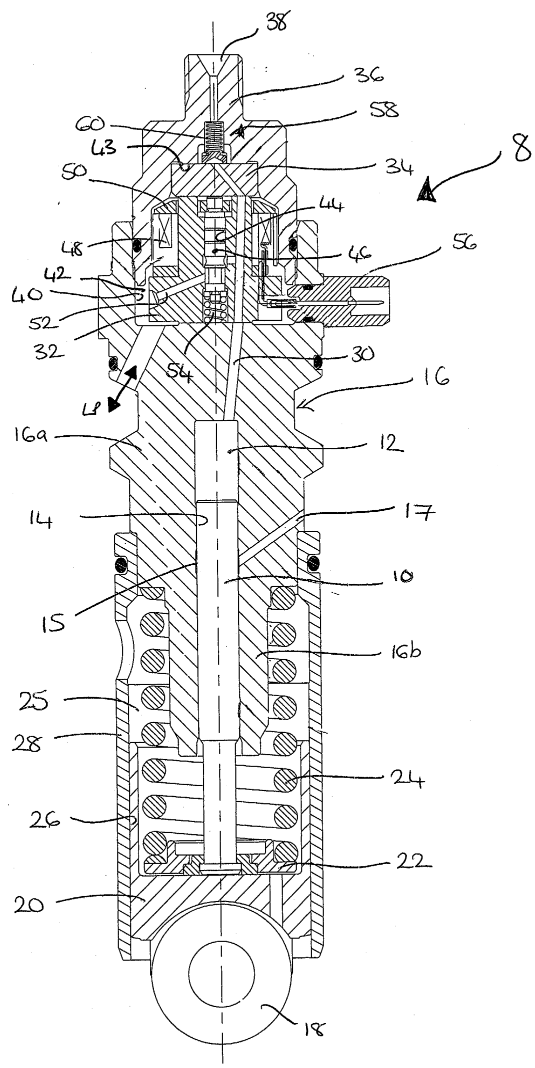

FIGURE 1

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Description

[0001] The present invention relates to common rail fuel system suitable for use, in particular, in a fuel injection system of a compression ignition internal combustion engine.

[0002] In known common rail fuel injection systems for diesel engines, it is common to provide a single high pressure pump for supplying fuel at an injectable pressure level to a plurality of associated injectors. The high pressure fuel pump supplies pressurised fuel to an accumulator volume or common rail, which is arranged to supply fuel to all of the injectors of the system. Typically, each injector is provided with an electronically controlled nozzle control valve to control movement of a fuel injector valve needle and, thus, to control the timing of delivery of fuel from the injector. The high pressure pump is commonly of radial pump design and requires a "rotary" drive. Radial fuel pumps also occupy a relatively large accommodation space.

[0003] Other types of diesel fuel injection system are known in which a plurality of unit pumps are provided, each of which delivers fuel at high pressure to a separate high pressure fuel line and, from here, to a dedicated injector. Each unit pump typically includes a tappet that is driven by means of a cam to impart drive to a plunger, thereby causing the plunger to reciprocate and resulting in pressurisation of fuel within a pumping chamber of the unit. In such systems it is necessary to provide each engine cylinder with a set of separate pump components, consisting of a cam, a tappet, a unit pump, a high pressure line and an injector, with the cams for each set of pump components being formed on a common drive shaft.

[0004] The unit pumps are arranged "in a line" along the axis of the cam shaft, with a drive end of each unit pump co-operating with a lobe of its associated cam and the injection nozzle end of each unit pump being arranged to deliver fuel to the associated engine cylinder. Typically, the cam shaft has three lobes associated with each engine cylinder; one for driving the associated pumping plunger and the other two for controlling engine valve timing.

[0005] It has been recognised that unit pump injection systems of the aforementioned type have their disadvantages. For example, each unit pump typically functions by pressurising a substantially fixed volume of fuel during a pumping cycle, and then spilling pressurised fuel that is not required for an injection event to low pressure. This introduces system inefficiency. Additionally, the system has a high part count, and therefore is of relatively high cost, particularly as it requires one unit pump to be provided for each fuel injector.

[0006] Despite the drawbacks of unit pump injection systems, the machining and assembly line facilities for the manufacture of engine installations of this type are well established, and engine installations designed to accommodate this type of system are widely used.

[0007] The problem addressed by the present invention is to provide a common rail fuel system that avoids or obviates the aforementioned disadvantages, whilst permitting continued use of production line facilities and engine installations that are already in existence.

[0008] According to a first aspect of the present invention there is provided a fuel system for an internal combustion engine, comprising a common rail fuel volume for receiving fuel at high pressure and for delivering said fuel to a plurality of fuel injectors and a unit pump assembly including a pumping plunger that is reciprocable within a plunger bore provided in a unit pump housing under the influence of a drive arrangement to cause fuel pressurisation within a pump chamber, wherein the drive arrangement includes a drive member coupled to the plunger to impart drive thereto, in use, so that the plunger performs a pumping cycle including a pumping stroke and a return stroke, a spill valve which is operable to control whether fuel is pressurised within the pump chamber during the pumping stroke of the plunger and an outlet valve for controlling the supply of pressurised fuel from the pumping chamber to the common rail fuel volume in circumstances in which the spill valve is closed.

[0009] The present invention provides a convenient, small and relatively lightweight fuel system, particular by virtue of the pump assembly being a compact unit. The fuel system has particular application in relatively small industrial and agricultural engines, although it may also be used in larger engines.

[0010] The provision of the spill valve provides a facility for inlet metering the quantity of fuel to be pressurised, if desired, and therefore avoids the requirement for a separate inlet metering valve to be provided for the pump assembly. A further benefit of the system is that it is compatible with existing engine installations and production line technology designed for unit pump injection systems, therefore providing cost benefits.

[0011] It will be appreciated that the pump assembly of the fuel system pressurises fuel for supply to the injectors of the system, but does so via the common rail fuel volume. The pump assembly of the fuel system may include a pump outlet which is in direct communication with the common rail fuel volume, or optionally communicates with the common rail fuel volume through additional pipework.

[0012] The drive arrangement typically includes a cam for driving the drive member and the plunger. If the fuel system is intended for use in smaller engines (for example one, two or three cylinders) a single unit pump assembly may be sufficient, with several lobes being provided on one cam if necessary. For larger engine applications (for example four, five or six cylinders), it may be necessary to provide a plurality of such unit pump assemblies.

[0013] Preferably, the spill valve of the pump assembly includes a spill valve member that is co-axially aligned with the plunger.

[0014] The outlet valve is preferably arranged within an outlet passage and the spill valve is preferably housed within a spill valve housing which is received within a recess or opening provided in an end region of the unit pump housing so that respective drillings provided in the spill valve housing and the unit pump housing align to define, at least in part, the outlet passage.

[0015] In a preferred embodiment the outlet passage communicates with a pump outlet which is substantially co-axially aligned with the spill valve member and/or the plunger.

[0016] Preferably, the outlet valve of the pump assembly is a hydraulically operable non-return valve located within the outlet passage.

[0017] The fuel system has several alternative modes of operation, and in particular several different methods may be used for controlling the quantity of fuel that is pressurised within the pump chamber and delivered to the rail.

[0018] In one mode of operation the pump chamber may be filled through the open spill valve during the plunger return stroke, with the spill valve being maintained open for an initial period of the pumping stroke so that some of the fuel within the pump chamber is dispelled back to low pressure. The spill valve is closed when it is required to initiate pressurisation of fuel within the pump chamber and is preferably opened again prior to a final period of the pumping stroke (i.e. prior to top-dead-centre). This method is advantageous as only a short period of spill valve actuation is required part way through the pumping stroke, providing an efficiency benefit and accurate control of the timing of fuel delivery to the rail. By opening the spill valve again prior to the final period of the pumping stroke Hertz stresses on the cam drive are also reduced.

[0019] In an alternative embodiment the spill valve may be actuable to close part way through the plunger return stroke so as to control the quantity that is delivered to the pump chamber for pressurisation during a subsequent plunger pumping stroke. In this case the spill valve therefore provides an inlet metering function. In this case the spill valve is preferably opened at or just after top-dead-centre.

[0020] The plunger bore of the pump assembly may also be provided with a filling port that is co-operable with the plunger to provide a filling function for the pump chamber, whereby when the plunger covers the filling port fuel is unable to flow into the pump chamber through the filling port and when the plunger uncovers the filling port fuel is able to flow into the pump chamber through the filling port.

[0021] The filling port may be defined at one end of a filling passage provided in the unit pump housing, wherein said filling passage communicates with a low pressure fuel reservoir.

[0022] The provision of the filling port and the filling passage provides a supplementary filling means for the pump chamber, which may be particularly advantageous if the supply pump for the system provides a supply pressure that is too low for filling through the spill valve.

[0023] In accordance with a second aspect of the invention, there is provided a unit pump assembly, suitable for use in the common rail system having the features set out in the accompanying claims, the unit pump assembly including a pumping plunger that is reciprocable within a plunger bore provided in a unit pump housing under the influence of a drive arrangement to cause fuel pressurisation within a pump chamber, wherein the drive arrangement includes a drive member coupled to the plunger to impart drive thereto, in use, so that the plunger performs a pumping cycle including a pumping stroke and a return stroke, a spill valve which is operable to control whether fuel is pressurised within the pump chamber during the pumping stroke of the plunger and an outlet valve for controlling the supply of pressurised fuel from the pump chamber to the common rail fuel volume in circumstances in which the spill valve is closed.

[0024] It will be appreciated that the unit pump assembly may be manufactured and sold independently of the common rail fuel volume, and may include any one or more of the optional or preferred features of the system of the first aspect of the invention.

[0025] According to a third aspect of the invention, there is provided a control method for a common rail fuel system as set out in the accompanying claims, the method including:

holding the spill valve open during the return stroke to permit fuel to be supplied to the pump chamber from low pressure,

closing the spill valve to permit pressurisation of fuel within the pump chamber during the subsequent pumping stroke, and

opening the spill valve prior to a final period of the pumping stroke so as to terminate pressurisation of fuel within the pump chamber and to ensure Hertz stresses on a cam of the drive arrangement are minimised.

[0026] The invention will now be described, by way of example only, with reference to the following drawings in which:

Figure 1 is a sectional view of a unit pump assembly forming part of a first embodiment of the present invention, and

Figure 2 is a sectional view of an alternative unit pump assembly forming part of an alternative embodiment to that shown in Figure 1.

[0027] Referring to Figure 1, a common rail fuel system of a first embodiment of the invention includes a pump assembly, referred to general as 8, having a pumping plunger 10 which is driven, in use, to pressurise fuel within a pump chamber 12 defined at the end of a plunger bore 14 provided in a main or unit pump housing 16. The unit pump housing 16 includes an upper region 16a of enlarged diameter compared to a lower reduced diameter region 16b. The plunger 10 is movable within the bore 14 under the influence of a cam drive arrangement, including an engine driven cam (not shown), which is mounted upon or forms part of an engine driven shaft and co-operates with a roller and a tappet arrangement 18, 20.

[0028] The plunger bore 14 is provided with a groove 15 to enlarge its diameter part way along its axial length. The groove 15 communicates with a drain passage 17 so as to permit leakage fuel from the pump chamber 12 through the plunger bore 14 to escape to low pressure.

[0029] A roller 18 of the drive arrangement co-operates with the surface of the cam as it rotates, in use. A lower end of the plunger 10 (in the orientation shown) projects from the plunger bore 14 and is coupled at its end to a tappet 20 through a spring plate 22. The plate 22 defines an abutment surface for one end of a plunger return spring 24, the other end of which engages with a step in the outer surface of the pump housing 16 between the enlarged 16a and reduced 16b diameter regions. At its lower end, the plunger 10 extends through and is coaxial with the return spring 24. The return spring 24 acts to provide a return spring force to the plunger 10 to effect a plunger return stroke, as will be described in further detail below, and is located within a return spring chamber 25 that is vented.

[0030] As the roller 18 rides over the cam surface it co-operates with the tappet 20 so as to impart a drive force to the tappet 20 and, hence, to the plunger 10. Tappet motion is guided by means of a guide bore 26 provided in an outer pump housing or sleeve 28 which is secured, at its upper end, to the unit pump housing 16. In an alternative embodiment (not shown) the sleeve may be removed, and instead the guide bore 26 may be provided directly within the engine block of the associated engine.

[0031] The pump chamber 12 communicates with one end of a first drilling provided in the upper region 16a of the unit pump housing 16. The first drilling defines a part of an outlet passage 30, or delivery passage, of the unit pump assembly through which high pressure fuel is supplied to a downstream common rail or accumulator volume of the fuel system. The common rail is not shown in Figure 1, but it will be appreciated that it may take the form of any accumulator volume for receiving high pressure fuel and for supplying fuel to a plurality of injectors of the fuel system. For example, the common rail may be of the linear rail type, in which the accumulator volume takes the form of an elongate pipe, or may of radial type, in which the accumulator volume has a central hub supplying a plurality of supply passages, each for supplying fuel to a different one of the injectors.

[0032] The outlet passage 30 of the pump assembly 8 is also defined by drillings provided in a spill valve housing 32, an insert 34 and a pump outlet housing 36 that is provided with a pump outlet 38 in communication with the common rail. The pump outlet 38 may communicate directly with the common rail or, optionally, through additional pipe work to the rail.

[0033] The pump outlet housing 36 is of generally U-shaped cross section, defining a downwardly extending annular wall and an internal end surface 43. The annular wall of the outlet housing 36 extends into a recess 40 provided at the upper end 16a of the unit pump housing 16. The recess 40 and the internal surface of the annular wall together define an internal chamber or housing space 42 within which the spill valve housing 32 and the insert 34 are received so that the spill valve housing 32 abuts the unit pump housing 16, at its uppermost end, and the insert 34 separates the spill valve housing 32 from the internal end surface 43. The pump outlet housing 36 is also provided with a pump outlet 38, one end of which communicates with the common rail and the other end of which receives fuel at high pressure through the outlet passage 30, in use.

[0034] The spill valve housing 32 forms part of a spill valve arrangement including a spill valve bore 44 within which a spill valve member 46 is movable under the influence of an electromagnetic actuator arrangement including a winding 48 and an armature 50 that is coupled to the spill valve member 46. The armature 50 is provided with a through drilling 51 through which a part of the spill valve housing 32 extends. The part of the spill valve housing 32 which extends through the drilling 51 defines a portion of the outlet passage 30 for high pressure fuel. The spill valve housing 32 is mounted relative to the unit pump housing 16 so that the spill valve member 46 is generally axially aligned with the plunger 10. It is a further feature of the invention that the pump outlet 38 is substantially co-axially aligned with both the spill valve member 46 and the plunger 10.

[0035] The spill valve arrangement takes the form of a single seat, two position valve that is operable to control communication between the outlet passage 30 from the pump chamber 12 (via the outlet passage 30) and a low pressure passage 52 defined within the spill valve housing 32. The passage 52 communicates with the housing space 42 which vents to low pressure.

[0036] Whether or not the outlet passage 30 communicates with the low pressure passage 52 is determined by the position of the spill valve member 46, which is movable between a first open state in which it is spaced from a spill valve seat (not identified) and a second closed state in which it seats against the spill valve seat. The spill valve member 46 is biased towards its open state by means of a spill valve spring 54. In order to close the spill valve the winding 48 is energised, attracting the armature 50 (i.e. movement of the armature in a downward direction in the illustration shown) and thereby causing the spill valve member 46 to move against the spring force into engagement with the spill valve seat. If the winding 48 is de-energised, the spill valve spring 54 serves to urge the spill valve member 46 away from the spill valve seat and, hence, the spill valve is opened.

[0037] Mounted upon one side of the unit pump housing 16 is an electrical connector arrangement 56 for providing a current to the winding 48 to control energisation and de-energisation thereof to open and close the spill valve, as required.

[0038] The region of the outlet passage 30 within the pump outlet housing 36 is provided with an outlet valve in the form of a hydraulically operable non-return valve 58 having a light non-return valve spring 60. The provision of the non-return valve 58 ensures high pressure fuel remains trapped within the common rail and cannot return to the outlet passage 30. Should fuel pressure within the outlet passage 30 exceed an amount that is sufficient to overcome fuel pressure in the rail (acting in combination with the spring force), the non return valve 58 is caused to open to permit high pressure fuel delivery through the pump outlet 38 and, hence, to the common rail.

[0039] The fuel system incorporating the pump assembly 8 shown in Figure 1 has several different modes of operation. In each mode, as the cam is driven to rotate the roller 18 is caused to ride or roll over the cam surface, thereby imparting a drive force to the tappet 20, and hence to the plunger 10, resulting in reciprocating motion of these parts 10, 20. The plunger 10 performs a pumping cycle during which it is driven inwardly within its bore 14 to perform a pumping stroke and urged outwardly from its bore 14 under the force of the return spring 24 to perform a return stroke.

[0040] A first, preferred mode of operation of the pump assembly will now be described. The winding 48 of the actuator is in a de-energised state at the start of the return stroke, so that the spill valve member 46 is spaced away from the spill valve seat under the force of the spill valve spring 54. With the spill valve open, continued movement of the plunger 10 through the return stroke causes fuel to be drawn into the pump chamber 12, filling the chamber 12 ready for the subsequent pumping stroke. At bottom-dead-centre the plunger 10 is at its outermost position within the bore 14, the pump chamber 12 is filled with fuel at low pressure and the winding 48 of the actuator is de-energised so that the spill valve member is in its open state in which it is spaced away from the spill valve seat. During the plunger return stroke the non return valve 58 is held closed as the force due to high fuel pressure within the rail, acting in combination with the spring 60, overcomes the force due to fuel pressure within the outlet passage 30 (in practice the non return valve spring force is relatively low and provides a much less significant force than rail pressure).

[0041] For an initial period of the pumping stroke (i.e. with the plunger moving between bottom-dead-centre and top-dead-centre) the spill valve is maintained in its open state so that some of the fuel that has been supplied to the pump chamber 12 is dispelled back through the open spill valve to low pressure. At this stage of the pumping stroke the non-return valve 58 will remain closed due to the pressure differential across it and the non return valve spring force holding it closed. Following this initial period of the pumping stroke (i.e. to a point part way through the pumping stroke on the accelerating part of the cam) the winding 48 of the actuator is energised to move the spill valve member 46 into engagement with the spill valve seat. Communication between the outlet passage 30 and the low pressure passage 52 is broken. With the spill valve closed and the pumping plunger 10 continuing through the pumping stroke and the volume of the pump chamber 12 reducing, fuel pressure within the pump chamber 12 increases until a pressure level is reached that is sufficient to cause the non-return valve 58 to open against the force of rail pressure (and the non-return valve spring 60). Pressurised fuel within the pump chamber 12 is therefore able to flow through the outlet passage 30, through the pump outlet 38 and into the common rail. The common rail communicates with the injectors of the fuel system, so as to permit fuel that is pressurised within the pump chamber 12 and supplied to the rail to be delivered to the injectors for injection.

[0042] Prior to the final period of the pumping stroke, and so before the plunger 10 reaches top-dead-centre, the spill valve is opened by de-energising the winding 48. When the spill valve is opened fuel pressure within the pump chamber 12 starts to reduce as communication is established between the outlet passage 30 and the low pressure passage 52. A point will be reached during the remainder of the plunger pumping stroke when the non return valve 58 is caused to close under the force of rail pressure and the non return valve spring 60, thus terminating the supply of fuel through the pump outlet 38 to the common rail. The spill valve is maintained in its open state during the subsequent plunger return stroke, to allow filling of the pump chamber 12 through the open spill valve, as described previously.

[0043] It has been recognised that by using this mode of operation, with the spill valve being opened prior to the final period of the pumping stroke, an advantage is achieved in that Hertz stresses on the cam are minimised. This arises because the pump assembly is only in a "pumping mode" (i.e. when fuel pressure within the pump chamber 12 is increasing) during periods of the pumping cycle for which the roller 18 is co-operating with regions of the cam form having a large contact radius. The method also requires the spill valve to be actuated to close only for a short period part way through the pumping stroke and thus provides an accurate means of controlling the timing of fuel delivery to the rail.

[0044] In a modification to this preferred mode of operation, a second mode of operation involves the same sequence of events as described previously, except that the spill valve is closed at an earlier stage of the pumping stroke, just after bottom-dead-centre and earlier on the accelerating part of the cam. Again the spill valve is opened just before the end of the pumping stroke.

[0045] In a third alternative mode of operation, the spill valve remains closed until after the plunger has passed top-dead-centre and commenced its return stroke. As the plunger starts the return stroke, moving towards bottom-dead-centre, the pressure of fuel within the pump chamber 12 starts to fall and a point will be reached during the plunger return stroke at which the non return valve 58 is urged to close as the force due to fuel pressure within the rail, acting in combination with the spring 60, overcomes the force due to fuel pressure within the outlet passage 30. When it is required to commence filling of the pump chamber 12, ready for the next pumping stroke, the winding 48 of the actuator is de-energised causing the spill valve member 46 to move away from the spill valve seat under the force of the spill valve spring 54. With the spill valve open, continued movement of the plunger 10 through the return stroke causes fuel to be drawn into the pump chamber 12 ready for the subsequent pumping stroke.

[0046] As described previously, having reached bottom-dead-centre at the end of the return stroke (i.e. just prior to commencement of the next pumping stroke), the plunger 10 starts to move inwardly within the bore causing some of the fuel that has filled the chamber 12 during the return stroke to be dispelled back to low pressure. The spill valve is then closed, in this case at a relatively late stage of the pumping stroke compared to the first and second modes of operation described previously, remaining closed until just after top-dead-centre as mentioned before.

[0047] In a fourth alternative mode of operation, the spill valve may provide an inlet valve means for the pump chamber 12 providing an inlet metering function. In other words the spill valve is operable so as to control the quantity of fuel that is supplied to the pump chamber 12 during a plunger return stroke for pressurisation during a subsequent plunger pumping stroke. The pump chamber 12 is therefore only filled for that period of the return stroke for which the spill valve is open.

[0048] During the plunger return stroke, when the spill valve member 46 would otherwise be biased away from the spill valve seat due to the force of the spring 54, the winding 48 of the actuator is energised to cause the spill valve member 46 to seat. Closing the spill valve part way through the return stroke provides a means for metering the quantity of fuel that is pressurised during a subsequent pumping cycle, as further movement of the plunger 10 through the return stroke with the spill valve closed prevents any further fuel to be drawn into the pump chamber 12. During the subsequent pumping stroke of the plunger 10 the spill valve remains closed so that the desired quantity of fuel that is pressurised within the pump chamber 12 is delivered through the open non-return valve 58 (once a pre-determined pressure is reached), into the pump outlet 38 and, hence, to the common rail.

[0049] After the plunger 10 has reached top-dead-centre and commenced the subsequent return stroke, the winding 48 is de-energised to open the spill valve, allowing the pump chamber 12 to re-fill during the return stroke, but only during an initial period of the return stroke, before closing the spill valve again to meter the quantity of fuel delivered to the pump chamber 12.

[0050] It will be appreciated that in all four modes of operation described previously, the spill valve controls the quantity of fuel that is pressurised within the pump chamber 12 during the pumping stroke, either by metering the quantity of fuel that is supplied to the pump chamber during the return stroke (fourth mode of operation) or by controlling how much fuel is dispelled from the pump chamber 12 during an initial period of the pumping stroke (first, second and third modes).

[0051] An alternative embodiment of the fuel system may include a pump assembly of the type shown in Figure 2. Similar parts to those shown in Figure 1 are identified with like reference numerals and will not be described in further detail. In Figure 2, the pump assembly 8 further includes a filling port 64 for the pump chamber 12 defined at one end of a filling passage 62 provided within the unit pump housing 16. The filling passage 62 communicates, at its end remote from the filling port 64, with a low pressure fuel supply or reservoir (not shown) so that as the plunger 10 reciprocates within the plunger bore 14 co-operation between its outer surface and the filling port 64 provides a supplementing fuel supply to the pump chamber 12 by controlling the supply of low pressure fuel through the filling passage 62 to the pump chamber 12.

[0052] The filling port 64 is positioned along the plunger bore axis so as to be uncovered by the plunger 10 only during an end period of the return stroke, typically over a plunger travel distance of, for example, between 2 and 4 mm. Fuel supply to the pump chamber 12 through the port 64 therefore only occurs during the end period of the plunger return stroke.

[0053] The embodiment of the invention in Figure 2 also has several different modes of operation. As described previously, filling of the pump chamber 12 through the spill valve occurs during the return stroke when the spill valve member 46 is unseated and additionally through the filling port 64 when it is uncovered by the plunger 10. Supplementary filling of the pump chamber 12 through the filling port 64 only occurs, however, if the pump chamber 12 is not already full at the point in the return stroke when the port 64 is uncovered, for example if supply pressure is too low to fill the pump chamber 12 completely through the spill valve.

[0054] In a first mode of operation the spill valve member 46 is held open for an initial period of the pumping stroke and is only closed after the point at which the filling port 64 has been closed by the plunger 10. During this initial period some of the fuel within the pump chamber 12 will be dispelled back through the open spill valve to low pressure, and additionally through the filling passage 62 (until the port 64 is closed by the plunger 10), as the plunger 10 continues through the pumping stroke. When it is required to supply pressurised fuel to the common rail, the winding 48 is energised to cause the spill valve member 46 to seat against the spill valve seat, thus closing the spill valve. As the filling port 64 is already closed at this time, closure of the spill valve causes pressure within the pump chamber 12 to increase. Subsequently, the non-return valve 58 will open and, hence, fuel at high pressure is delivered through the pump outlet 38 to the common rail.

[0055] In an alternative mode of operation of this embodiment, the winding 48 is energised to seat the spill valve member 46 at an earlier stage of the pumping cycle, and before the plunger 10 has closed the port 64. In such circumstances it is closure of the port 64 by the plunger 10 that causes pressurisation of fuel within the chamber 12, subsequent opening of the non-return valve 58 and, hence, high pressure fuel delivery through the pump outlet 38 to the common rail.

[0056] In both the first and second modes of operation of the pump assembly 8 in Figure 2, the winding 48 is de-energised before the final period of the plunger return stroke (i.e. prior to top-dead-centre), causing the non return valve 58 to close to trap high fuel pressure within the common rail. As mentioned before, the benefit of using this method is that Hertz stresses on the cam are minimised as the plunger 10 is only pumping during periods for which the roller 18 is co-operating with regions of the cam form having a large contact radius.

[0057] In a third alternative mode of operation of the pump assembly 8 in Figure 2, the winding 48 is energised at a later stage of the pumping stroke, after the filling port 64 is closed, so as to seat the spill valve member 46. Subsequently, the non-return valve 58 will open and, hence, fuel at high pressure is delivered through the pump outlet 38 to the common rail. The spill valve member 46 is held in this position for the remainder of the pumping stroke and so that fuel delivery to the rail continues until plunger top-dead-centre. Only after the plunger has commenced the return stroke is the winding de-energised to unseat the spill valve member 46, thus permitting filling of the pump chamber 12 through the spill valve ready for the subsequent pumping stroke. The non return valve 58 is caused to close to trap fuel pressure in the rail at just about top-dead-centre.

[0058] The present invention is advantageous in that it can be readily incorporated into existing engine installations, for example unit pump type installations, where the available accommodation space is limited. The pump assembly of the system is also relatively compact, particularly due to the actuator (i.e. the spill valve member 46, the armature 50 and the winding 48) being located co-axially with the plunger 10, and being mounted within a housing 32 adjacent to, and directly on top of, the unit pump housing 16 for the plunger 10 and its associated drive components 18, 20. The fuel system therefore provides size and weight benefits also.

Claims

1. A common rail fuel system for an internal combustion engine, the system including:

a common rail fuel volume for supplying pressurised fuel to a plurality of fuel injectors of an engine,

a unit pump assembly (8) for supplying pressurised fuel directly to the rail volume, the pump assembly having a pumping plunger (10) that is reciprocable within a plunger bore (14) provided in a unit pump housing (16) under the influence of a drive arrangement (18, 20) to cause fuel pressurisation within a pump chamber (12), wherein the drive arrangement includes a drive member (20) coupled to the plunger (10) to impart drive thereto, in use, so that the plunger (10) performs a pumping cycle including a pumping stroke and a return stroke, and a spill valve (46) which is operable to control whether fuel is pressurised within the pump chamber (12) during the pumping stroke of the plunger (10) and an outlet valve (58) for controlling the supply of pressurised fuel from the pumping chamber (12) to the common rail fuel volume in circumstances in which the spill valve is closed.

2. The common rail fuel system as claimed in claim 1, wherein the spill valve of the pump assembly (8) includes a spill valve member (46) that is co-axially aligned with the plunger (10).

3. The common rail fuel injection system as claimed in claim 1 or claim 2, wherein the outlet valve (58) is located within an outlet passage (30) and wherein the spill valve is housed within a spill valve housing (32) arranged relative to the unit pump housing (16) so that respective drillings provided in the spill valve housing (32) and the unit pump housing (16) align to define, at least in part, the outlet passage (30).

4. The common rail fuel system as claimed in claim 3, wherein the outlet passage (30) communicates with a pump outlet (38) which is substantially co-axially aligned with the spill valve member (46) and/or the plunger (10).

5. The common rail fuel system as claimed in any one of claims 1 to 4, wherein the outlet valve of the pump assembly (8) is a hydraulically operable non-return valve (58) located within the outlet passage (30).

6. The common rail fuel system as claimed in any one of claims 1 to 5, wherein the spill valve provides an inlet metering valve for the pump chamber (12), whereby closure of the spill valve part way through the plunger return stroke controls the quantity of fuel that is supplied to the pump chamber (12) for pressurisation during a subsequent plunger pumping stroke and for delivery to the common rail.

7. The common rail fuel system as claimed in any one of claims 1 to 5, the spill valve being actuable to open throughout the return stroke to permit filling of the pump chamber (12) and to close following an initial period of the pumping stroke, thereby to permit a quantity of fuel within the pump chamber (12) to be dispelled through the spill valve to low pressure during the initial period.

8. The common rail fuel system as claimed in claim 7, wherein the drive arrangement is driven by means of a cam, and wherein the spill valve is operable to open prior to a final period of the pumping stroke so as to minimise Hertz stresses on the cam.

9. The common rail fuel system as claimed in any one of claims 1 to 8, wherein the plunger bore (14) is provided with filling port (64) provided in the plunger bore (14), wherein the plunger (10) is co-operable with the filling port so that when the plunger (10) covers the filling port (64) fuel is unable to flow into the pump chamber (12) and when the plunger (10) uncovers the filling port (64) fuel is able to flow into the pump chamber (12).

10. The common rail fuel system as claimed in claim 9, wherein the filling port (64) is defined at one end of a filling passage (62), provided in the unit pump housing (16), wherein said filling passage (62) communicates with a low pressure fuel reservoir.

11. The common rail fuel system as claimed in any one of claims 1 to 10, wherein the drive member of the pump assembly (8) is a tappet (20).

12. The common rail fuel system as claimed in any one of claims 1 to 11, wherein the spill valve of the pump assembly (8) is a two-position, single seat valve.

13. The common rail fuel system as claimed in any one of claims 1 to 12, comprising a plurality of unit pump assemblies.

14. A unit pump assembly for use in a common rail fuel system as claimed in any one of claims 1 to 13.

15. A control method for a common rail fuel system as claimed in any of claims 1 to 14, wherein the drive arrangement is driven by means of a cam, the method including:

holding the spill valve (46) of the unit pump assembly open during the return stroke to permit fuel to be supplied to the pump chamber (12) from low pressure,

closing the spill valve (46) to permit pressurisation of fuel within the pump chamber (12) during the subsequent pumping stroke, and

opening the spill valve (46) prior to a final period of the pumping stroke so as to terminate pressurisation of fuel within the pump chamber and to ensure Hertz stresses on the cam are minimised.

16. The control method as claimed in claim 15, whereby the spill valve (46) is closed after an initial period of the pumping stroke so as to dispel a proportion of fuel that is supplied to the pump chamber (12) during the return stroke back to low pressure.

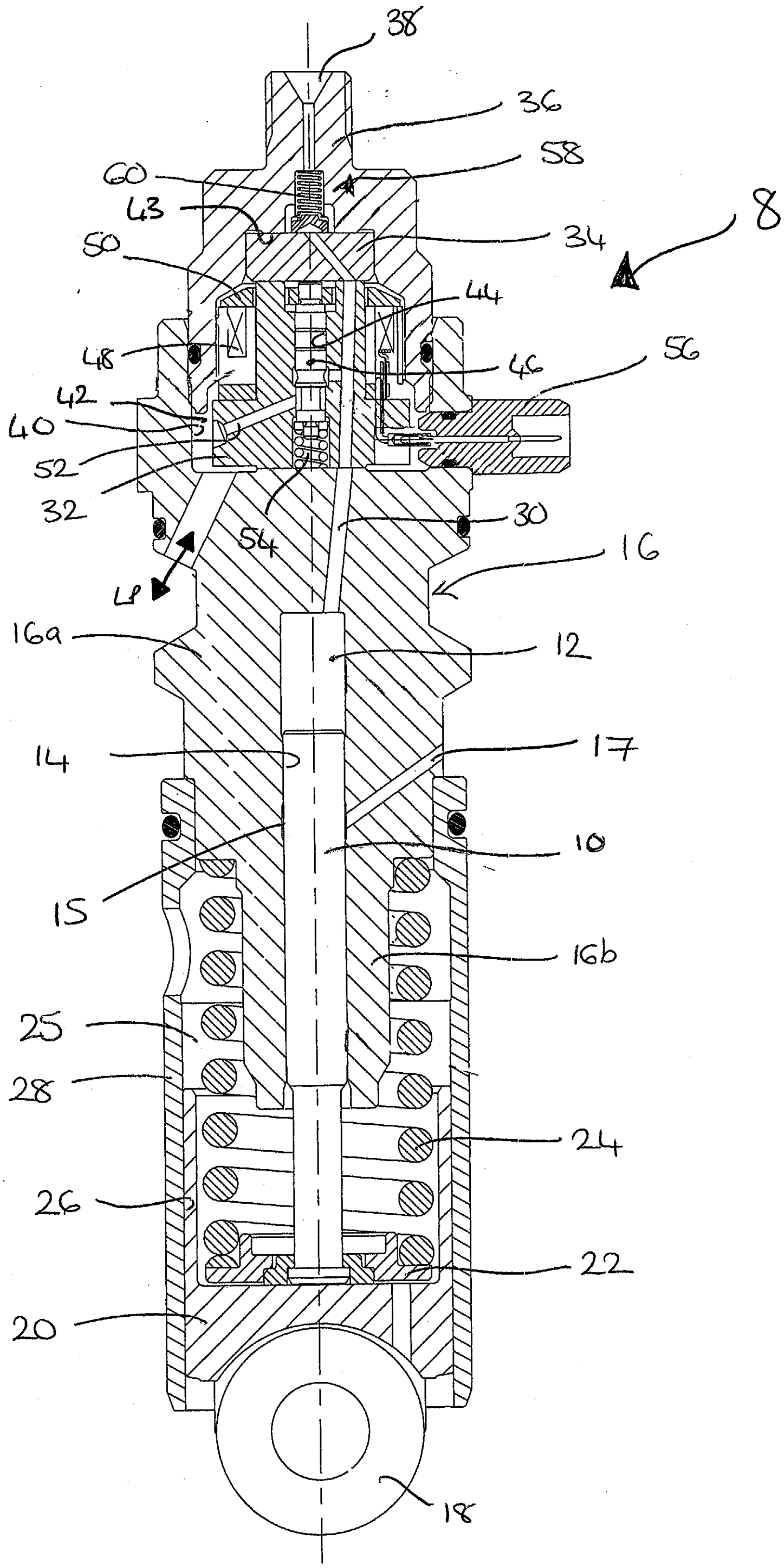
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FIGURE 1

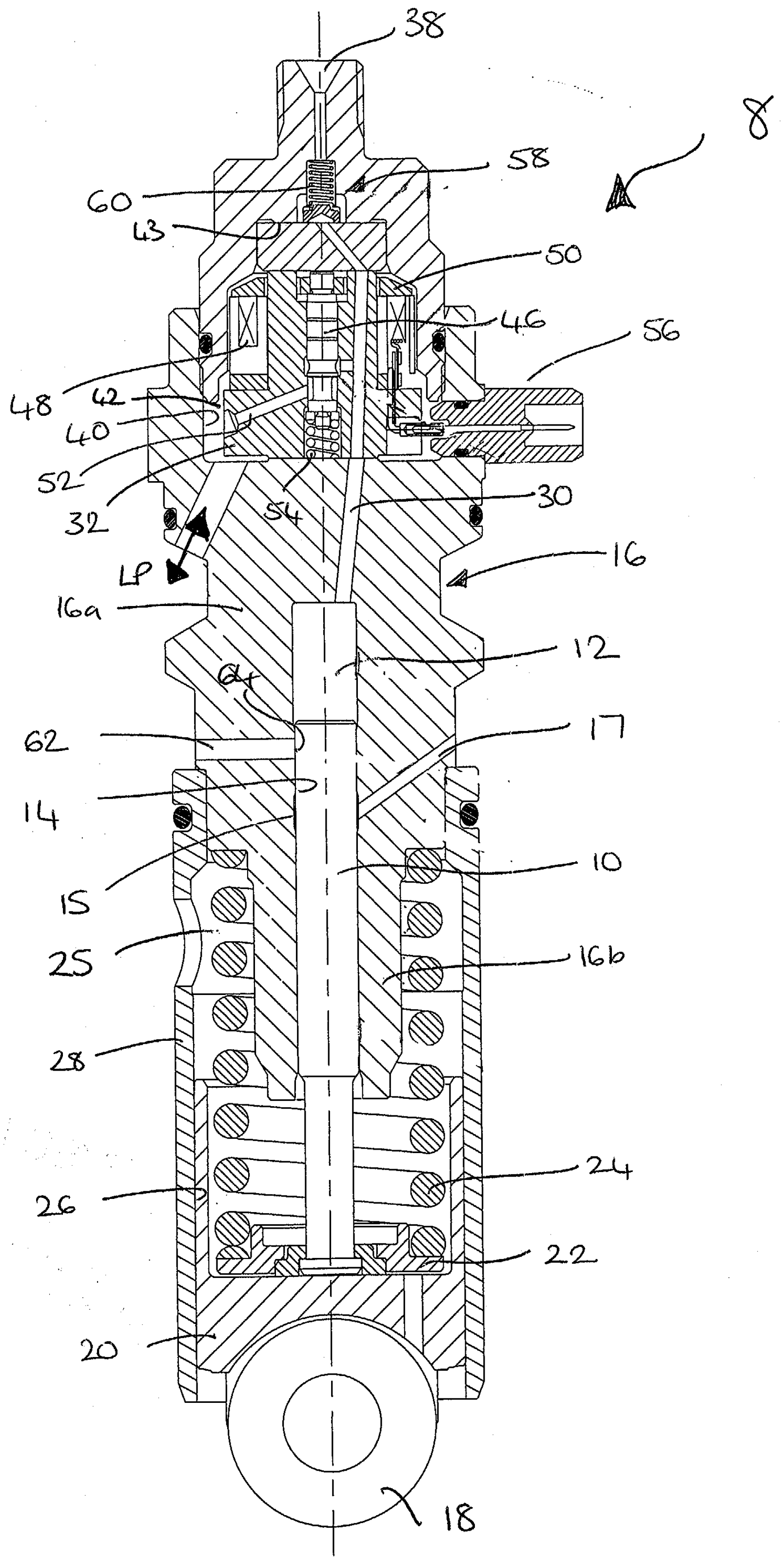
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FIGURE 2

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EUROPEAN SEARCH REPORT

Application Number
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F02M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	17 November 2003	Torle, E

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